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WEST VIRGINIA UNIVERSITY
AGRICULTURAL EXPERIMENT STATION,
MORGANTOWN, W. VA.

BULLETIN ~~86.~~ 87 MAY, 1903.

# GREENHOUSES.

BY L. C. CORBETT.

[The Bulletins and Reports of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of Agricultural Experiment Station, Morgantown. West Va.]

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THIS is one of several bulletins reporting work under way during the incumbency of Prof. L. C. Corbett, as Horticulturist at this Station, but prepared for publication by him after his resignation of that position and his acceptance of work as Horticulturist of the Bureau of Plant Industry, in the United States Department of Agriculture, at Washington, D. C.

J. H. STEWART,
Director.

*West Virginia Agricultural Experiment Station*
[FIGURE 1]

# Comparative Durability of Greenhouse Walls.

THE first greenhouse built on the Experiment Station Grounds, and which comprises sections A, B and C as shown in the ground plan, Fig. 2, was constructed in three sections. The two end sections having brick walls while the center section had a wood wall and side lights arranged to admit of side ventilation. The south section is of brick and comprises room A, 20x30 feet in dimensions. The walls of this section consist of two 4-inch walls built up from the foundation 4 inches apart and not tied together by either metal ties or brick header courses. The construction of the roof structure throws the whole weight and thrust of the roof on the outer 4-inch wall. At present this wall is in bad condition, having bulged badly, cracked in several places notwithstanding one portion of it has been relaid. This wall, while maintaining a large air space, a very desirable feature, is not well adapted to greenhouse construction. In the first place, the load is entirely thrown on the outside wall, which is only four inches thick. The inside wall is exposed to the drip and moisture which gathers and runs down inside the roof structure. To overcome the evil effects of this a coat of cement was placed on top the wall and against the gutter, but the spread of the house has thrown the gutter away from the cement and allows the moisture to get inside the wall. Water is in itself a very destructive agent to brick walls, and when combined with frost which during cold weather is capable of penetrating the outer wall the destructive disintegration of the combined action of frost and water becomes considerable. The conception of this

wall is on the correct basis for a greenhouse wall, but the air space between the two walls is too great, and the walls are not sufficiently tied together to make one a support for the other. This wall was built in the fall of 1892, and now after eight years' use will have to be rebuilt. The side walls of section B of the house built in 1892 were constructed of wood. A brick foundation was built to the surface of the ground, and on top of this a board wall consisting of 2x4 studding against which building paper and " novelty seeding " were placed on the outside; on the inside the paper was covered by matched flooring. This construction was brought up to within 18 inches of the plate. The space between the plate and the top of the wooden wall being fitted by hinged sash. This wall stood until the fall of 1899 (7 years) when it was so badly decayed that it was torn out and replaced by a 9-inch brick wall. This is about the average life of a greenhouse wall constructed in this manner. For this section of the United States where both lumber and brick are comparatively cheap, and where a 9-inch wall will answer for the side wall to a green house, it is poor economy to build the wood walls. For a temporary house, however, one with wood walls constructed upon posts set in the ground as hereafter described, proves very satisfactory. Section C of the house built in 1892 has a solid brick wall 12 inches thick. This wall is now in as good condition as when first built. It has not sprung out of line, and seems to be capable of withstanding the elements for years to come. In this climate where we have comparatively few cold days and no protracted cold periods, the solid wall is not objectionable. One criticism is to be made on both sections, A and C, of the first greenhouse built, that is, the walls are four inches wider than the plate. The plates are so arranged as to throw the gutter flush with the outside surface of the wall, which consequently leaves the water table four inches wide on the inside of the house. Such an arrangement is very undesirable for the drip and condensation on the inside of the glass is constant-

ly running down on top of the wall, a condition very detrimental to the wall. This, of course, has nothing to do with the wall itself. It is merely a question of superstructure. All the greenhouse walls built since those above described have

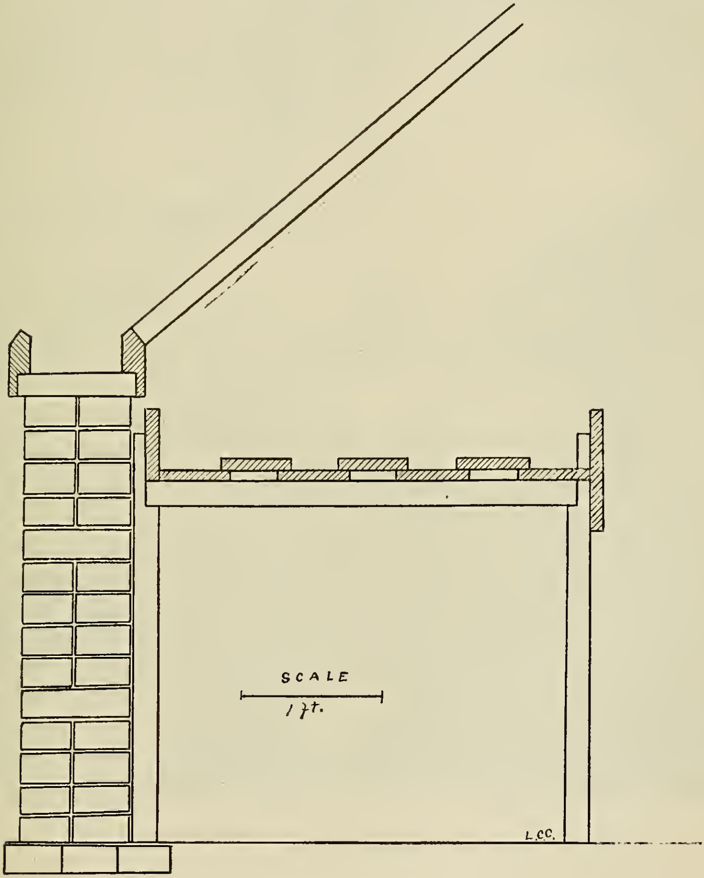



*Fig. 2.*

been constructed of brick, laid in double courses so as to form a *nine* inch wall with about one-half inch air space between the two layers of brick. These were laid in the five course sections, every sixth course being a header course, i. e., a course

laid across the wall so that the end of the brick, the 2x4 inch way is exposed. This construction when hard bricks are laid with good sand and Portland cement makes a most satisfactory wall for this climate and one which is sufficiently strong for all ordinary forcing houses. For large conservatories a heavier foundation would be necessary. For all practical purposes the 9-inch wall just described is best. The regular greenhouse construction material is worked to fit such walls, and as they are less expensive both in material and labor, they are to be preferred if just as good.

## WOOD WALL FOR A TEMPORARY GREENHOUSE.

Where a somewhat cheaper construction than any of the above is desired, a greenhouse wall can be very satisfactorily built of wood. A temporary structure of this character for the use of the station was built as follows: Locust posts were set in the ground and rough fencing boards nailed to the outside, another layer of rough boards was likewise placed on the inside of the posts and the intervening space filled with mill shavings. The tops of the posts were sawed off at the angle of the roof, and a 2x10 inch plank nailed on top so as to cover the whole of the lower structure. The rafters were cut so that the top of the rafter was flush with the top of the plate. As the plate was two inches thick, this left two inches of the 2x4 on the under side of the plate, which provided ample material for securely nailing it to the heavy plate, and the roof structure completed by putting hot-bed sash on top. This arrangement was constructed to take the place of a hot-bed, which it did with good results. If a more durable and warmer wall were desired, the rough boards could be covered with a layer of tarred building paper and over the paper siding. This would, of course, increase the cost by the price of the paper and siding. This construction, provided with a brick flue for heating, worked very satisfactorily.

*West Virginia Agricultural Experiment Station*
[FIGURE 3]

## GREENHOUSE BENCHES.

The first requisite in a greenhouse bench is strength; the second, fitness for the crop to be grown upon it: third, durability.

The first requirement can be secured by the use of either wood or iron supports. In either case, however, the one essential point to be kept constantly in mind is to have the trusses or supports close together so that the material used for the bottom of the bench will not spring and allow the bench to get out of place. If wooden trussels or horses are used, they should stand 3 to 3½ feet apart, 3 feet being best. A support can be made of 2x4 oak in the manner shown in Fig. 1, which, if set 3 feet apart on brick or stone foundations prove very satisfactory. By nailing the face board to the outside and the back board inside the legs, a neat construction is secured which accomplishes a very desirable end. The one-inch thick projecting portion of the leg fits closely to the wall of the greenhouse, but as the back board is placed inside these projecting ends of the legs, an air space one inch wide is left between the wall and the back of the bench, as shown in Fig. 2. This space which allows of a free passage of warm air from the pipes into the space formed by the top of the bench and the roof is a very great advantage. The air into the space over the bench is tempered by a direct current of warm air passing from the pipes through the inch space, by which the temperature near the back of benches is kept the same as that at the front. If the warm air were prevented from passing from the pipes through the inch space, by which the temperature near the back of benches is kept the same as that at the front. If the warm air were prevented from passing from the pipes through the inch opening, its route would be toward the center of the house and upward, and the space over the back of the benches would be warmed only by diffusion of air. Actual temperature readings show that from 2 to 4 or even 6 degrees difference in temperature may exist between the front and the back of benches

if the bench is built tight against the wall in such a manner as to stop the passage of air from the pipes back of the bench. This difference is also readily manifested by the growth of the crop at the front and at the back of a bench so constructed. Lettuce is very quick to manifest such differences. In houses which are maintained at a low temperature, say 40 deg. F. it is not an infrequent occurrence to find the temperature 40 deg. over the center bench of a three-bench house, and the plants frozen at the outer edge of the side benches. By placing the side board next the walk on the outside of the trussels as shown in Fig. 2, a smooth side is left which makes the carrying of the hand borrow or flats much easier than where the trussels are left on the outside of the bench.

The construction of the bottom of the bench for ordinary forcing purposes would seem to offer little opportunity for variety. A simple rough board floor does pretty well, but such a floor always presents the disadvantage of a single thickness of boards. Such boards can seldom be laid tight enough to prevent cracks of considerable width, through which heat acts directly upon the soil and plant roots. By the drying action of the heat against the boards the cracks grow wider, soil sifts through, the beds dry unevenly and heat is as unevenly distributed. If narrow boards (6 in.) are used and spaced as shown in Fig. 2, and the spaces covered by a second board lapping about an inch over the board on either side of it, a tight construction is secured which gives a uniform distribution of heat, prevents unequal drying of the soil, and make a much stronger and more durable bench floor than can be secured with a single thickness of lumber arranged in any other manner.

## SUB-IRRIGATION.

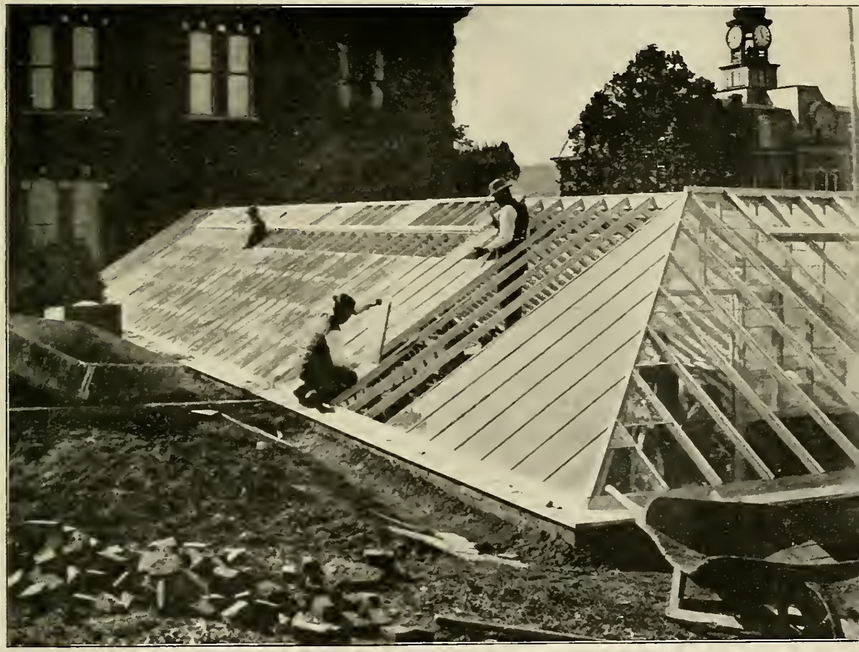
This construction is not adapted for sub-irrigation. Sub-irrigation can only be carried out successfully where the bench floor is water-tight. Such a floor can be secured by using flooring laid in lead, but our experience with such floors built of

good yellow pine is that they are only fit for sub-irrigation a single season; the second year they can be used as an ordinary bench floor, but longer than that they cannot be relied upon. Such a construction is very expensive, and since it is not permanent can hardly justify the expense for the increase in the crop secured. In a forcing house built in 1894, sections of a bench were covered with large pans made of copper, lead, zinc and galvanized iron. These have since remained in constant use, and are now serving their seventh season in apparently as good condition as when placed in the greenhouse. While the first cost of these benches was much more than that of a wooden bench, yet the cost of these would in comparison with cost of renewing the wooden bench at the end of ten years, show a balance in favor of the metal benches. The house in question has had four board floors built in the benches. The first one was matched yellow pine laid in lead, but not painted. This floor served for sub-irrigation one year and as an ordinary bench floor one year. A spruce floor served one year. This was replaced by an oak floor laid in the manner shown in Fig. 1; lumber used was old fence boards, which lasted three years. This last floor was again replaced the present fall (1900) by one laid in the same way from old fence boards. Counting the cost of lumber at \$12 per M for the spruce and oak, and \$30 per M for the flooring, together with the expense of laying, we have a cost of about \$7.50 per square (100 square feet) for the board floor, against \$22 for galvanized iron; \$9.20 for zinc; \$30 for copper and \$30 for the lead. Thus showing that even in six years the metal benches have a very favorable showing. Then, too, the metal benches have been in a perfect condition to admit of such irrigation during the whole period. While metal benches have been in constant use for six years in a house where benches variously constructed of wood could be compared with them both as regards their durability and their effect upon the growth of plants, no detrimental influences have been observed from the use of the metal. The large mass of soil in the

benches as compared with that in pots or cans in which individual plants are grown seems to be able to counteract any injurious result which might be expected to follow from the use of the metal benches. The soil acids are undoubtedly constantly acting upon the metal of the bench, and while even the slight solution of copper, zinc or iron which results might prove detrimental to the plants were they to remain permanently upon the bench and the soil become thoroughly incorporated with roots. Yet, since the soil itself is renewed annually, and the crops which are usually grown on such benches seldom occupy them more than two or three months, the injury to any individual plant, or even to a crop must be very slight. Our experience, therefore, leads us to favor the use of metal bench linings where sub-irrigation is to be practiced. I am not sure but that the metal lining will not prove much cheaper in the long run than slate or wood for ordinary greenhouse benches.

## DIVIDED BENCHES.

It frequently happens that there is great variation in the air temperature over wide benches. Such variations are not conducive to best growth in plants requiring a warm atmosphere, such as roses do. In order to overcome the ill effects of the wide bench, the individual bench has been conceived. A 7-foot bench which occupies the center of the rose house has been cut into two narrow benches, each 3 feet four inches wide. This allows a 4-inch space between the two sections. No floor is placed in this section, and the open space between the two portions acts as a register through which warm air from the heating pipes comes directly in contact with the growing bushes. This not only provides a congenial air bath for the leaves and growing parts, but aids in maintaining a uniform degree of heat over the entire surface of the bed. The advantage of such a scheme was suggested by an experience in attempting to grow roses on a bench with no bottom heat, but which was higher and separated from a bench with bottom heat by a walk



*West Virginia Agricultural Experiment Station*
[Figure 4]

two feet wide. The roses in the border row of the bench which received a bath of warm air from the pipes under the adjacent bench grew nicely, and did well while the plants occupying a more remote position near the center of the bench all died. The bench was torn out, pipes placed in position to furnish bottom heat, and the bench above described built over them. The result is that roses thrive well and the bench is now the best one of the three in the house. The bottom heat is to be credited with a large share of the good, but there is no question but that the bench is better for being constructed in sections.

## GREENHOUSE VENTILATORS.

As a rule, greenhouse ventilators are placed near the ridge of the house and on one side or the other of the ridge pole. If a house stands with its long axis running north and south, the ventilators are either on the east or west side of the roof, according to the fancy of the builder or, if he be thoughtful, on the side away from the prevailing winds. If the ventilator sash are hinged at the ridge, they are usually placed on the east side of the roof, unless the locality be one in which east winds are cold and prevalent. With such an arrangement, whether it be east or west, a wind from the direction in which the ventilators open allows a direct draft of air into the house. Such a current of air blowing into the house is reflected by the roof of the house in such a way as to throw it directly upon the benches. With a line of sash hinged either at the comb or at the bottom of the sash, the result is practically the same. But with the sash hinged at the bottom, less wind blows into the house than when the sash are hinged at the comb. The ideal ventilator, however, is one consisting of two narrow lines of sash, one on either side of the comb and hinged at the bottom of the sash so as to make a broad flue or opening in the top of the house when the ventilators are open. Such a construction is slightly more expensive than the single run of ventilators, but the efficiency of it as compared with the other plans is far

superior. Wind blowing from the east or from the west in this case cannot blow into the house, while winds from the north or south may blow through between the open lines of sash, but since there is no obstruction to reflect them upon the benches, direct cold drafts are more effectively prevented than by any other form of ventilator. One reason why this style is not met with more frequently is that only one or two of the lifters now on the market are adapted for this work. The two forms which have come under my notice which work well on a ventilator designed to open at the ridge are the Carmody and Chicago. Both are simple, durable and work easily, although they are noisy. By using the Chicago gear and placing one of the saw-blade arrangements on top, and the other under the revolving shaft, the difference in direction necessary to lift and close the two sash is secured. Two years' use has amply demonstrated the advantage of this form of ventilator and the fitness of either of the types of lifter above mentioned needs no comment.

## DISTILLATION OF SULPHUR.

Sulphur fumes are one of the main dependences of florists and greenhouse men in warding off or checking attacks of mildew upon greenhouse plants. The common method of securing this end is to place shallow pans of sulphur upon the heating pipes; or to scatter it upon the pipes as a powder, or even to mix it with oil and paint the pipes with the paint so made. All these methods are more or less convenient, but they seldom result in giving more than a slight odor of sulphur dioxide in the house. To accomplish the desired ends where a much stronger treatment is needed, as frequently occurs in lettuce and cucumber houses, the following scheme devised by the writer accomplishes the purpose and at the same time overcomes the great danger of contingent or bringing sulphur over an open flame.

Description of the Device:—A small two-burner kerosene

stove is used to guarantee the desired heat. Over the flame of this stove is placed ordinary cake tins such as are used for baking layer cakes—pie tins will answer. In this a quantity of sand sufficient to make a layer ½-inch deep was placed. The sulphur is then put into a second and smaller pan and placed upon the sand in the larger. In this way heat sufficient to keep the sulphur melted is secured without danger of its becoming overheated and ignited. The scheme is the sand bath applied to sulphur fumigation for greenhouse. The device was first figured in American Garden, Vol. 16, page 331, and again in Cornell University, Bulletin No. 96, is here reproduced in Fig. 5.

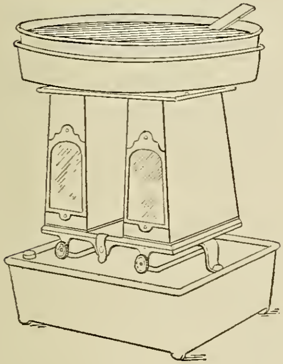


*Fig. 5.*

## HINTS ON GREENHOUSE CONSTRUCTION.

Modern greenhouse construction has had as one of its chief ends the lessening of the light obstructing framework. Sash bars have been substituted for sash and rafters. Large glass have replaced those of small size. Clear glass is almost universally employed on forcing houses and commercial greenhouses in place of the ground glass formerly so extensively employed and still used on the better conservatories. This revolution has in many cases been carried to the extreme. Long slender sash-bars placed wide apart in order to accommodate large glass makes a very unstable structure. While such a frame may not actually break under the strain of heavy storms, the springing of the framework usually results in a heavy loss from the breakage of glass. Even if the glass is not actually broken, the constant springing of the structure loosens the joints of the roof, breaks the bond between glass and putty, so that a leaky roof is almost inevitable. Another

extravagance which follows the endeavor to secure light is the large glass which is much more expensive for a given area than glass of small size. Mr. Rawson, who has carried this idea farther than any other commercial grower in America, and who once built a house and roofed it with glass 24x36 inches, is now using glass about 14x20 as a compromise. There is at the West Virginia Experiment Station a bank of three houses each 20 feet wide by 60 feet long. The primary object of these houses is, of course, to furnish proper conditions and facilities for conducting experiments with plants under glass; the construction of the walls, roof and benches has been carried out with the idea of furnishing reliable information concerning the advantages or disadvantages of certain types of structure for the conditions prevailing in West Virginia. The first one was built in 1892; another in 1894 and another in 1898. The houses built in 1892 and 1894 were framed from cypress sash-bars designed to carry butted glass. The bars are 12 feet long and 2¼ deep by 1½ inches broad, supported about midway between gutter and ridge by a wooden purline. These bars are set 16 inches apart, and carry 16x24 D. S. glass. The roofs as laid when the houses were built was "butted", but the spring of the roof, together with the difficulty of constructing a greenhouse roof on this principle made it almost impossible to keep them from leaking. Constant calking was necessary and even then drips would be detected in most injurious quarters. In 1898 both these roofs were taken off and re-laid; one was again butted, the other lapped. The "butted" roof served one winter, after which it was considered too much of a nuisance to be longer tolerated; accordingly strips were obtained and nailed to the sash-bars which formed a cleat to allow lapped glass to be properly fastened in place. In 1898 a new house, as has already been stated, was constructed, and instead of using sash-bars of the dimensions above stated, a cypress bar 1½ inches broad by 3 inches deep was secured. The sash-bars on the new house were the same length as those in the

other two houses, and run from gutter to ridge. Instead of being carried by a wooden purline, as in the other two, they are supported about midway by an iron purline made of 1¼-inch gas pipe. The purline is supported by cross-arms made of 1½-inch gas pipe, and are also made a part of the standard which supports the ridge pole by being firmly screwed into a 4-way T or cross. The sash-bars are strapped to the iron purline by iron straps held in place by two screws. A portion of one end of one of the iron purlines is seen in Fig. 1. This construction forms a truss roof which can neither sag nor spread. The house has now stood two years, does not leak, and has only two cracked glass in its roof. Both the other houses in which the lighter sash-bars were used required repair work even before the first winter—after the roofs were re-laid—was over and the breakage in the roof of house D, Fig. 2, alone required one and one-half boxes of glass to repair it. With glass at $4.56 per box, this is a big interest to pay for increased light and lessened cost of construction. Speaking of increased light, it is a question whether house D is as light as houses E and F, even with their heavier roof structure. There is probably an advantage in this respect which would be more apparent were the houses differently located in reference to one another. As at present arranged, houses E and F have an advantage in that they are not covered by a house at the east side. Granting all possible advantage of light to be secured by the lighter construction, I am still of the opinion that the heavier sash-bars are more desirable from an economic standpoint. The heavier roof structure will certainly stand longer, and the breakage of glass in two years is sufficient to cover the difference in cost of material. What has been said applies only to the use of large glass, 16x24 or 14x20. For smaller sizes which require a closer placing of the bars, and which have more joints or laps in a course of glass, the spring in the roof is of less consequence. Then, too, the closer spaced sash-bars increase the strength of the house, but

cut out more light. A just proportion exists between the size of the glass and the dimension of the sash-bars to be used. For 16x20 or 16x24 glass the bars should be 1½x3 inches, while for glass 14x20 or less the bars may be 2¼x1½, and for 12x14 glass with sash-bars 12 inches apart, a bar 1x1¾ will be ample, provided it is not too long, and has proper purline supports. The wind pressure against a house of given dimensions is the same, no matter what the size of the glass. The roof structure should possess the same strength, therefore, whether the bars stand 12 or 16 inches apart. For it is wind pressure that we have to provide against, and not the weight of the glass itself. My experience leads me to say, use deep, narrow sash-bars, well supported by iron purlines. Wood purlines are not stable enough. Cover the house with A quality double strength (D. S.) glass. Lap the glass, making the lap 1-8 to 3-16 inches wide, nail well in place and have glass well bedded in putty of best whiting and oil. Poor putty is an expensive investment. As ordinarily manipulated, laying lapped glass is a very tedious job, but our experience has been that by using the scheme hereinafter described, lapped glass can be more quickly and cheaply put in place than butted glass.

## LAYING LAPPED GLASS.

The old and reliable lapped glass roof for greenhouses will probably never go out of fashion, but the cost of laying it and the tedious method usually employed have induced many to seek a substitute in other styles, such as the "butted" and zinc strip scheme for laying roofs. The method of laying lapped glass here described is so simple and so easily learned, by even an unskilled laborer, that it cannot fail to meet a much felt want. The method is as follows: If the work is to be done during cool weather, which is not desirable, choose a warm room, and upon a table about two feet high arrange a board very like the kneading board used by the pastry cook. This board should be wide, smooth and perfectly flat. Warm a quantity of putty, say five or eight pounds, sufficiently to

make it soft and pliable, but not sticky. With the hand spread the putty over the board in a layer of uniform width and of a length as great as that of the glass to be used, and with a section of chree or four inches vitrified sewer pipe, as a rolling pin, roll the putty out into a thin layer about 3-16 of an inch thick. Then with the glass held as shown in Fig..3, i. e., with the ends firmly grasped in the hands, the convex side of the glass away from the operator, and the edge of the glass about $\frac{1}{4}$-inch back from and parallel with the edge of the putty. Press the glass through the putty so as to cut off a narrow strip. Tip the pane toward the operator then backward, and draw it forward. This operation will loosen a strip of putty which will adhere to the edge of the glass as seen in the upper side of glass in Fig. 3. Change sides with the glass and repeat the operation, then with a putty knife cut off the ends of the two lines of putty sufficiently to allow for the desired width of lap. Pass the glass to a man on the roof, holding it meanwhile with the putty on top. The man on the roof turns the pane over and presses it firmly in place (see Fig. 4), thus squeezing out any superfluous putty which will pass in both directions out of the rabbit of the sash-bar, as soon as the glass is fastened in place the operation is complete, save for cleaning off superfluous putty. One man can putty glass for two men on the roof to lay. By that I mean he can spread putty, open boxes and putty and hand up sufficient glass to keep two men on the roof busy adjusting and fastening it in place. In building a new house a record was kept of the time required to cover one side of a house 20x30 feet; the sash-bars were 12 feet long and 16 inches apart. Three men, using 16x24 inches D. S. glass put the roof on one side of this house in $2\frac{1}{2}$ hours, which is quicker than the same area of butted glass could have been laid and the caps screwed down. The roof has now stood two winters and one summer, and does not leak a drop. Laying a lapped glass greenhouse roof was a great undertaking until this method was hit upon, but now it is one of the simplest and quickest parts of greenhouse construction.